Remarks on possible P-violation in heavy ion collisions

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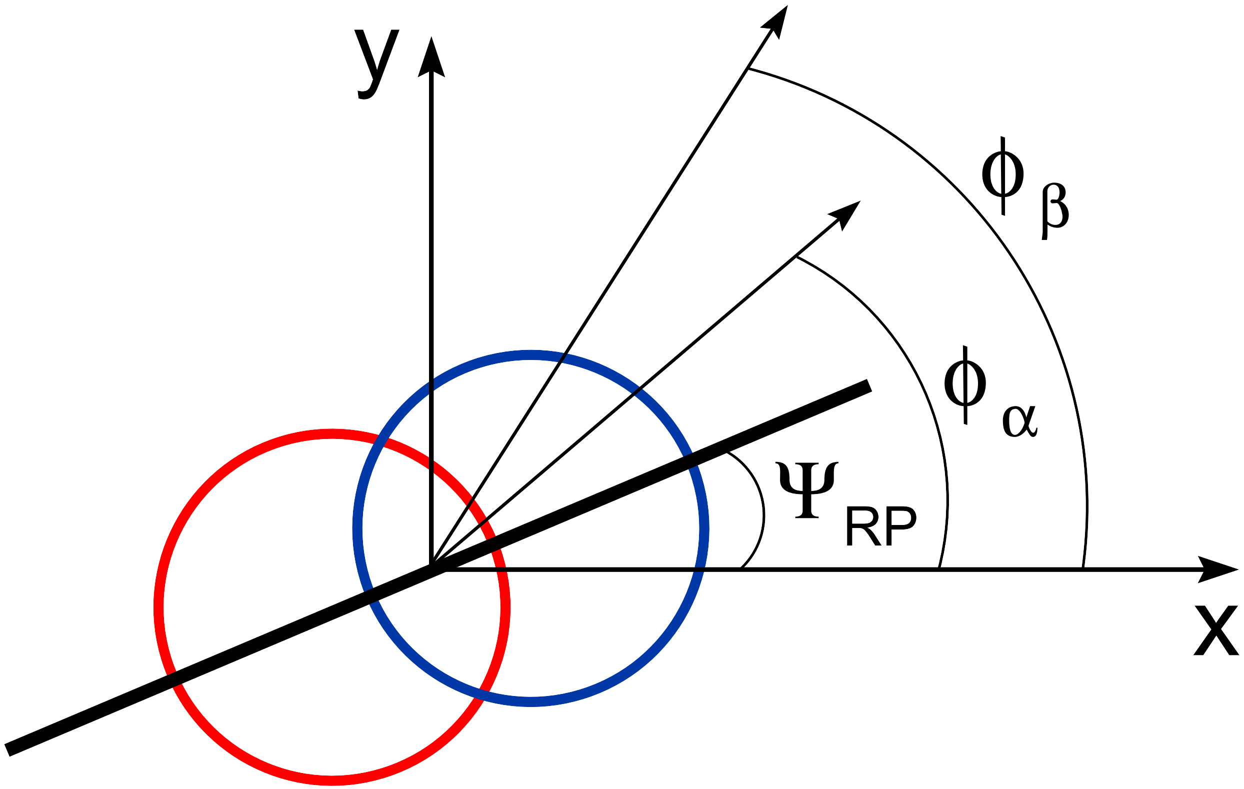
Outline

- short introduction
- integrated signal
- p_t distribution
- conclusions

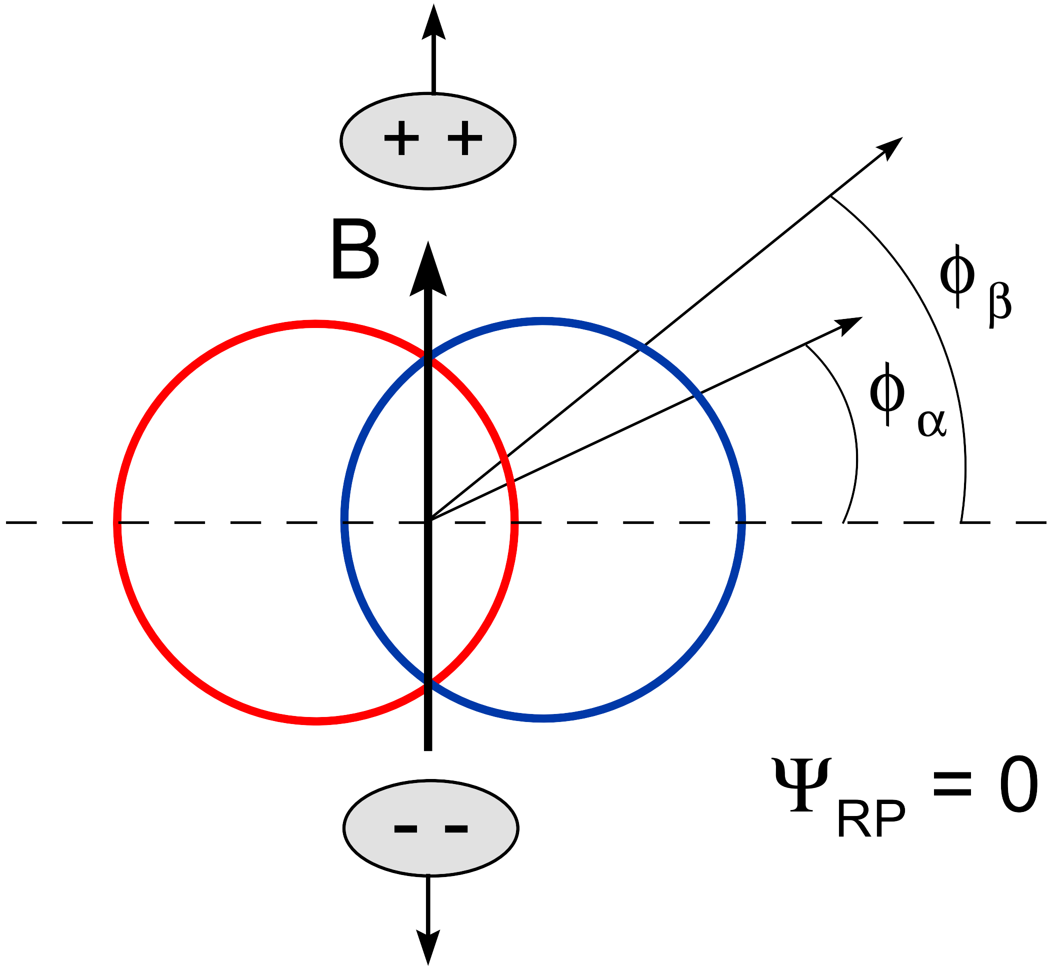
Introduction

Reaction plane



$\boxed{\textbf{We work in the frame where } \mathbf{\Psi_{RP} = 0}}$

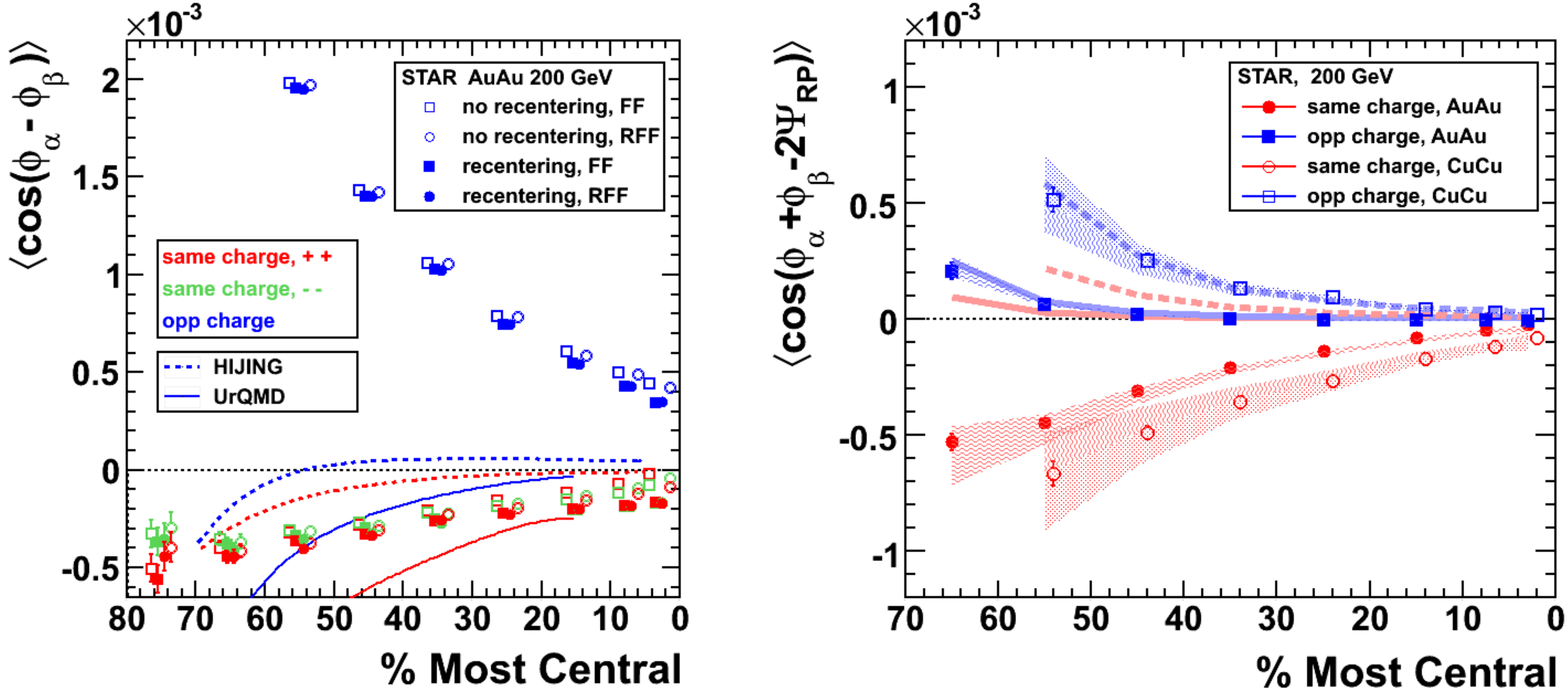
Chiral Magnetic Effect



$$\boxed{\text{for same sign pairs: } \langle \sin(\phi_\alpha)\sin(\phi_\beta)\rangle > 0}$$

Integrated signal

STAR data



$$\boxed{\left\langle \cos(\phi_\alpha - \phi_\beta) \right\rangle_{same} \simeq \left\langle \cos(\phi_\alpha + \phi_\beta) \right\rangle_{same} < 0}$$

$$\left\langle \cos(\phi_\alpha - \phi_\beta) \right\rangle_{opposite} > 0; \quad \left\langle \cos(\phi_\alpha + \phi_\beta) \right\rangle_{opposite} \approx 0$$

from:

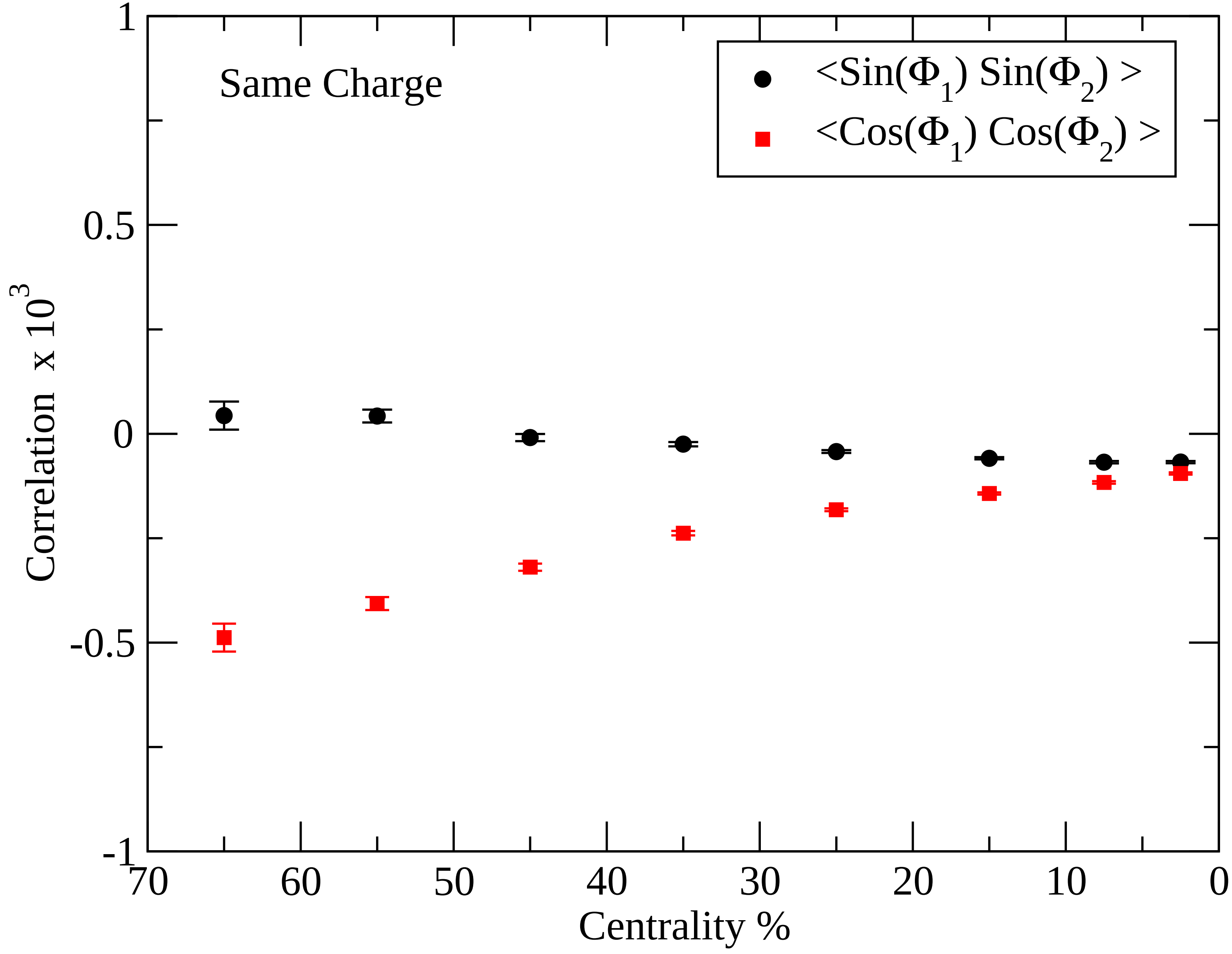
$$\left\langle \cos(\phi_\alpha - \phi_\beta) \right\rangle = \left\langle \cos(\phi_\alpha) \cos(\phi_\beta) \right\rangle + \left\langle \sin(\phi_\alpha) \sin(\phi_\beta) \right\rangle$$
$$\left\langle \cos(\phi_\alpha + \phi_\beta) \right\rangle = \left\langle \cos(\phi_\alpha) \cos(\phi_\beta) \right\rangle - \left\langle \sin(\phi_\alpha) \sin(\phi_\beta) \right\rangle$$

we obtain:

$$\begin{aligned} \left\langle \sin(\phi_\alpha) \sin(\phi_\beta) \right\rangle_{same} &\simeq 0 \\ \left\langle \cos(\phi_\alpha) \cos(\phi_\beta) \right\rangle_{same} &< 0 \end{aligned}$$

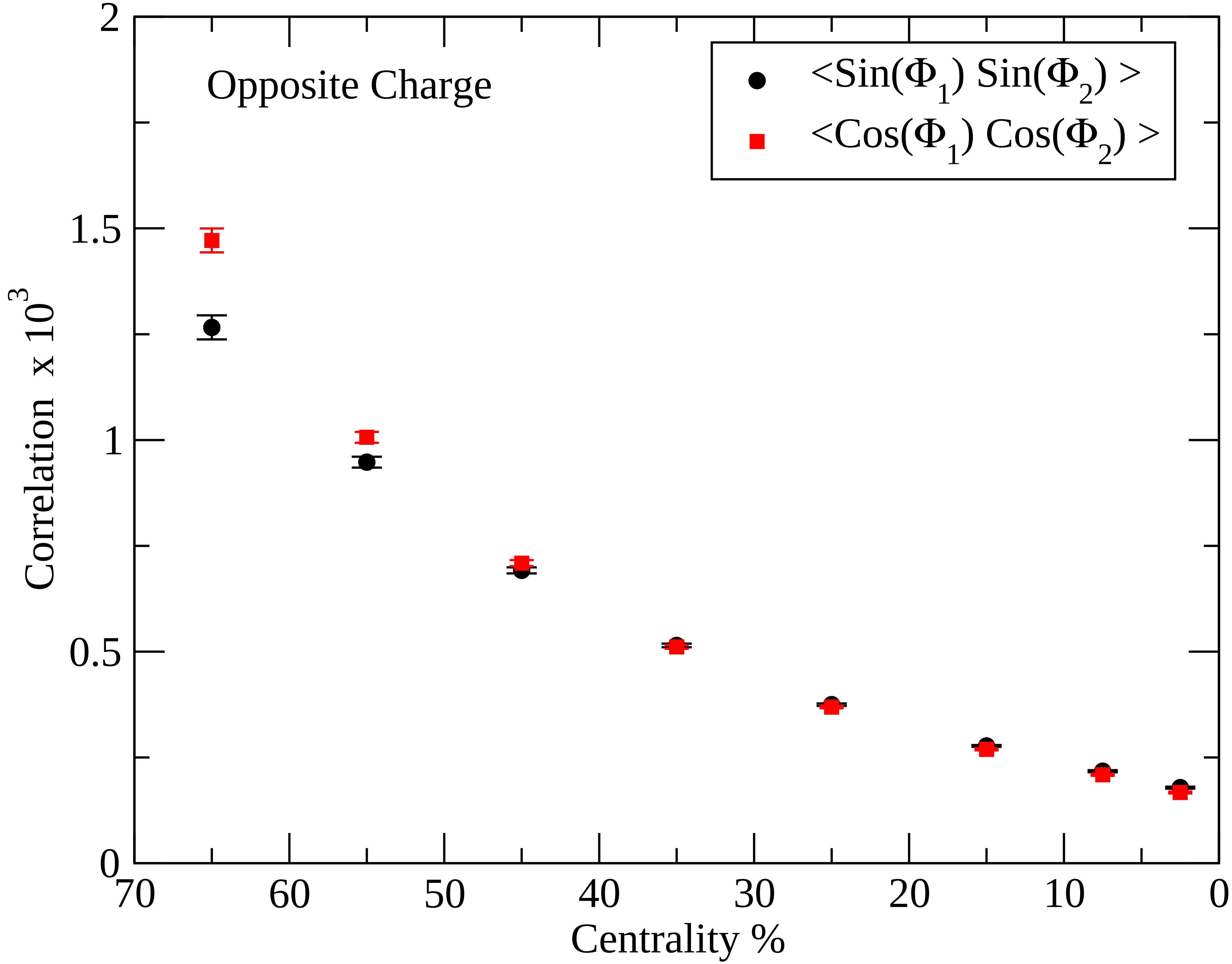
$$\left\langle \sin(\phi_\alpha) \sin(\phi_\beta) \right\rangle_{opposite} \simeq \left\langle \cos(\phi_\alpha) \cos(\phi_\beta) \right\rangle_{opposite} > 0$$

Same sign



Same Charge
<Sin(Φ1) Sin(Φ2) >
<Cos(Φ1) Cos(Φ2) >
1
0.5
0
-0.5
-1
Correlation x 10^3
70
60
50
40
30
20
10
0
Centrality %

Opposite sign



where is the parity?

$$\left\langle \sin(\phi_\alpha)\sin(\phi_\beta) \right\rangle_{same} \equiv P + B_{out}$$

$$\left\langle \sin(\phi_\alpha)\sin(\phi_\beta) \right\rangle_{same} \simeq 0$$

in consequence:

$$\boxed{\mathbf{P \simeq -B_{out} \simeq -B_{in}}}$$

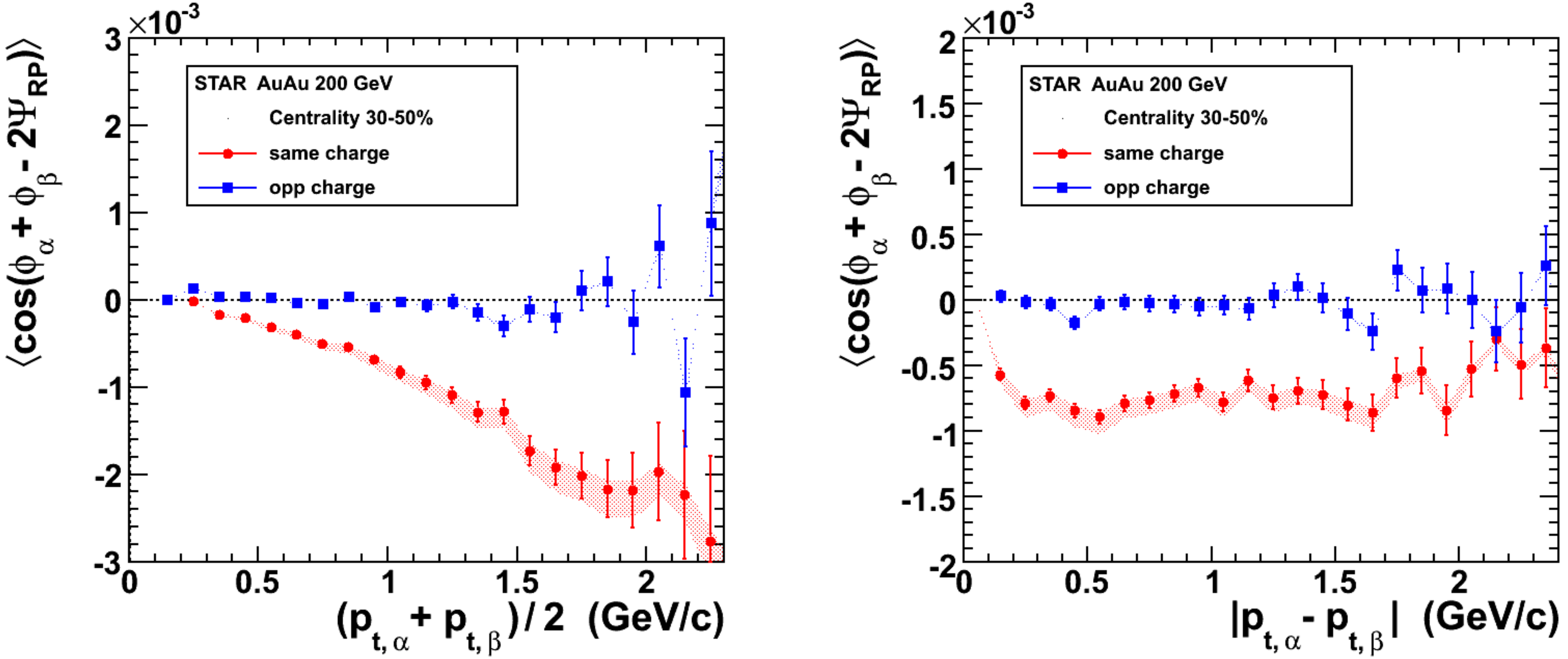
This is an unexpected relation:

maybe it is lucky coincidence?

in order to answer that question we need differential (p_t, η) $\left\langle \cos(\boldsymbol{\phi_\alpha} + \boldsymbol{\phi_\beta}) \right\rangle$ **and** $\left\langle \cos(\boldsymbol{\phi_\alpha} - \boldsymbol{\phi_\beta}) \right\rangle$

p_t distribution

STAR data



$\langle\cos(\phi_\alpha + \phi_\beta)\rangle \propto p_{t,\alpha} + p_{t,\beta}$ and very weak dependence on $|p_{t,\alpha} - p_{t,\beta}|$

We will show that the true signal is located at low p_t

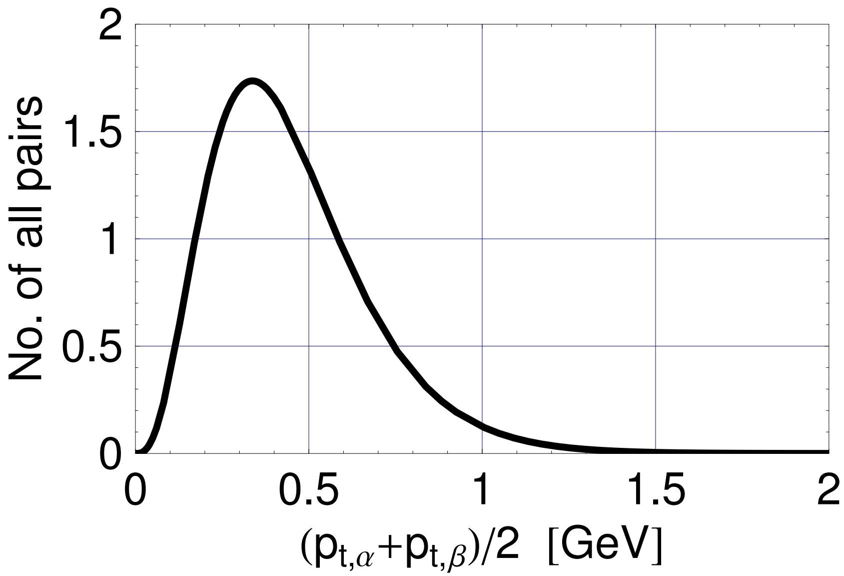
Definition:

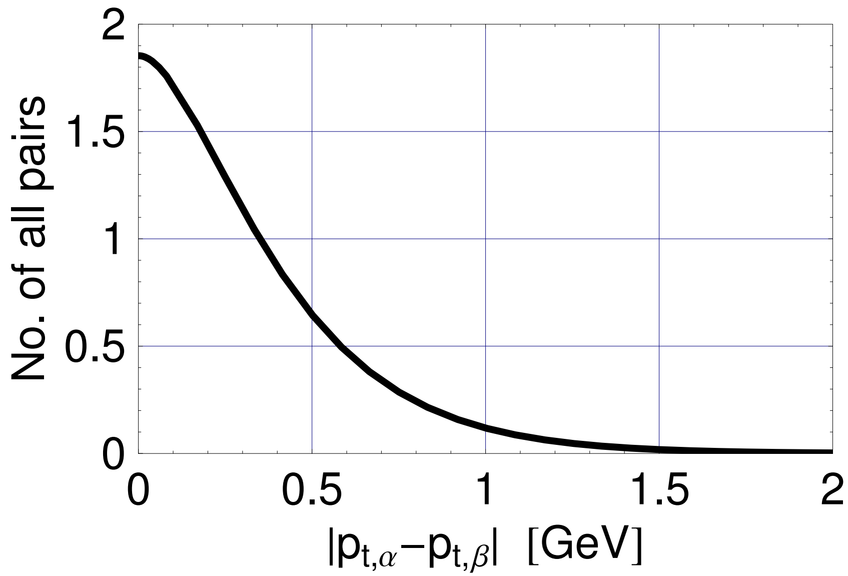
$$\left\langle \cos(\phi_\alpha + \phi_\beta) \right\rangle = \frac{\text{No. of correlated pairs } [\,\cos(\phi_\alpha + \phi_\beta)]}{\text{No. of all pairs}} \sim \frac{1}{1000}$$

We can calculate the (differential) number of all pairs:

$$\int \exp\left(\frac{-p_{t,\alpha}}{T}\right) \exp\left(\frac{-p_{t,\beta}}{T}\right) d^2p_{t,\alpha} d^2p_{t,\beta} \bigg|_{\substack{\text{fixed } p_{t,\alpha}+p_{t,\beta} \text{ or} \\ \text{fixed } |p_{t,\alpha}-p_{t,\beta}|}}$$

The number of all pairs vs $(p_{t,\alpha}+p_{t,\beta})$ and $\left|p_{t,\alpha}-p_{t,\beta}\right|$



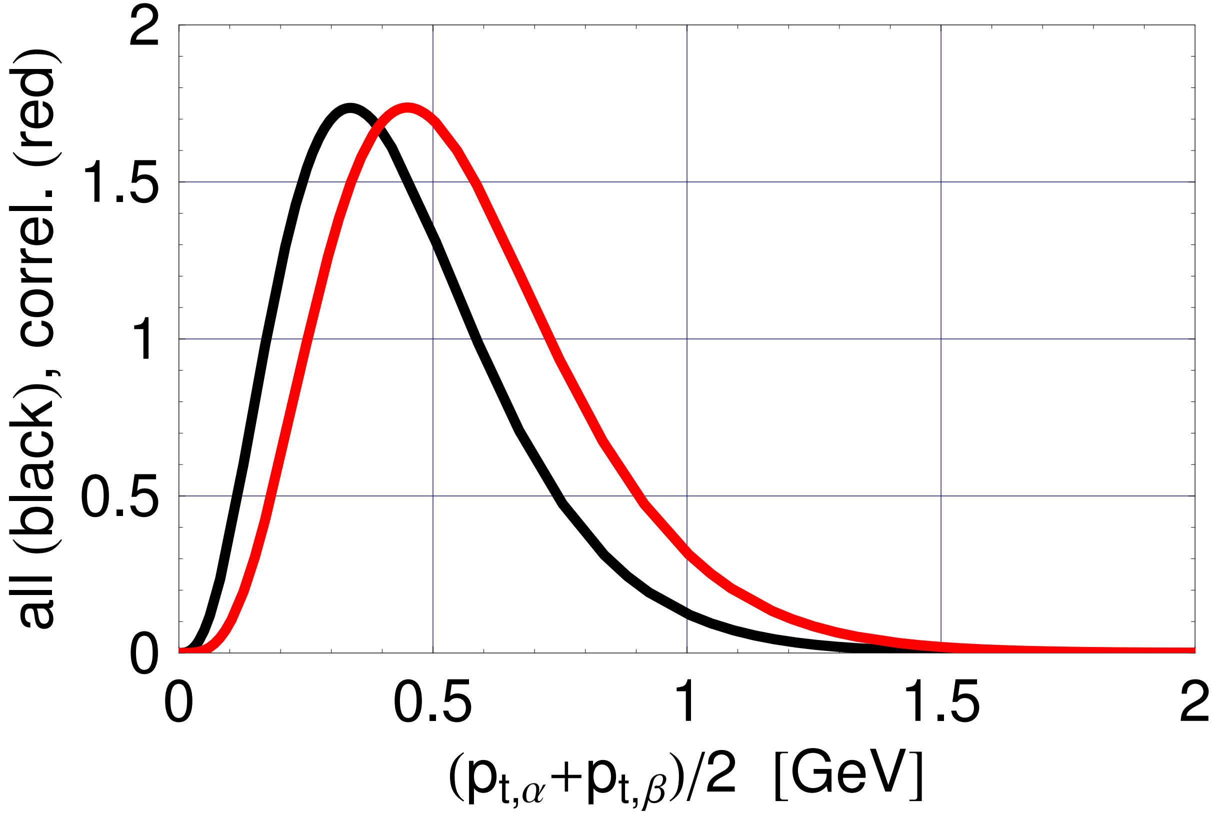


From that we can obtain p_t dependence of the number of correlated pairs:

– $\left|p_{t,\alpha}-p_{t,\beta}\right|$ distribution is as above (right plot)

– and multiply the left plot by $(p_{t,\alpha}+p_{t,\beta})$ ...

... we obtain [all pairs (black), correlated pairs (red)]



It is enough to give a small (100 MeV) $\mathbf{p_t}$ boost to all correlated particles

The observed signal is NOT inconsistent with the Chiral Magnetic Effect

Conclusions

- for same sign STAR sees large correlations in-plane and very small correlations out of plane
- parity signal must almost exactly cancel background
- maybe it is lucky coincidence
- we need differential $\left\langle \cos(\phi_\alpha - \phi_\beta) \right\rangle (p_t, \eta)$ to answer that question
- signal is dominated by $p_t < 1$ GeV and this is consistent with the Chiral Magnetic Effect
- each correlated particle needs small (100 MeV) p_t boost